Non-Load-Test Sling Request Form

REVISON LOG

REV	DESCRIPTION	DATE
Basic	H77-0382-01/-02 SRM Segment Break-over Structural Slings.	03/11/2015

APPROVALS

TITLE	NAME	ORG	SIGNATURE	DATE
TOSC Mech Sys Engr	Bryan Salisbury	TOSC		3/20/15
TOSC Mech Systems Architect	Dan Pouliot	TOSC		3/20/15
TOSC SMA	John Garrett	TOSC		3/23/15
NASA DE/NE CE	HECTOR N. DELGADO	NE-0		3/24/15
KSC LDEM	Malcolm Glenn	SA-C2	malcolm Glenn	3/25/15
NASA Sys Engr	Greg Katnik PERRY BECKER (FOR)	GP-6		3/25/15
GSDO/NE SE	Jorge Rivera	NE-0		3/25/15
GSDO CSO	John Branard	SA-F		3/25/15
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GSDO PRB Chair	Phil Weber	LX		3/25/15
TOSC CE	MICHAEL G. WYCKOFF	TOSC		3/25/2015

SLING INFORMATION

SLING NAME: STRUCTURAL SLING, BREAK-OVER, SRM SEGMENT	
PMN: H77-0382-01 / -02	**S/N: 400 / 500**
OTHER IDENTIFIER (e.g. DWG #): 80K22313 / 79V22313	
DATE OF REQUEST: 03/11/2015	**REQUESTING ORG: TOSC 5400**

NOTE:

The NASA Lifting Standard, NASA-STD-8719.9, allows for non-load test slings as follows:

10.3.3 Non-Load Test Slings. Due to unique design and usage requirements, a sling may be designated as a non-load test sling by the LDEM, with concurrence from the affected/responsible program/project office, the responsible safety, design engineering, systems engineering, operations, and maintenance organizations. Such slings do not require periodic load tests. Inspections shall be conducted in accordance with paragraph 10.4. This non-load test designation shall be formally documented by each installation and the sling marked accordingly to designate it as a non-load test sling.

DESCRIPTION OF THE PERIODIC LOAD TEST THAT WILL NOT BE PERFORMED

The annual periodic load test of the H77-0382 SRM Segment Break-over Structural Slings per paragraph 10.3.2 of the NASA Lifting Standard, NASA-STD-8719.9 will not be performed.

10.3.2 Periodic Load Testing.
Slings shall undergo periodic load test at least every 4 years at a specific load test factor of the design rated load as given in Table 10-3. All components shall be load tested as a system, if practical. Slings used for critical lifts shall be load tested at least once per year. Slings used infrequently for critical lifts shall be load tested before each critical lift if it has been over a year since the last load test. Lifting interfaces such as eyebolts, D-rings and lifting lugs permanently attached to the load are exempt from periodic load testing.

TABLE 10-3 Periodic Load Test Factors. (Based on Manufacturer's Rated Load)

Equipment	Periodic Load Test Factor
Alloy Steel Chain Slings	1.00
Wire Rope Slings	1.00*
Metal Mesh Slings	1.00
Synthetic Rope Slings	1.00
Linear Fiber Slings	1.00
Structural Slings	1.00
Shackles, D-rings, turnbuckles, Eye Bolts, Lifting Lugs, Safety Hoist Rings, etc.	1.00

*Critical lift rope slings of synthetic material shall not be used beyond 50 percent of the manufacturer's rating to maintain an equivalent design factor in the load system.

NOTE: The H72-0382 SRM Segment Break-over Structural Slings shall be deemed a non-load test sling as described in NASA Lifting Standard, NASA-STD-8719.9, Paragraph 10.3.3 (Non-Load Test Slings). Such slings do not require periodic load tests. Inspections shall be conducted in accordance with paragraph NASA-STD-8719.9 Paragraph 10.4.

SLING DESCRIPTION
General: The H77-0382 (-01 and -02) SRM Break-over Structural Slings were specifically designed and are exclusively used for SRM booster segment off-loading at the Rotation Processing and Surge Facility (RPSF).
Design Standards: The slings meet the following design standard requirements: KSC-DE-512-SM (Facility systems, Ground Support Systems and Ground Support Equipment general design requirements) KSC-STD-Z-0004F (Structural Design, Standard for) KSC-STD-Z-0002 (Lifting Devices and Equipment, Standard for) superseded by NASA-STD-8719.9
Design Factors: Analysis (KSCL-3231-0904) verifies a minimum factor of safety of 5 against ultimate and 3 against yield (matches munition and Nuclear industry design requirements).
Material/Construction Properties: The slings are constructed from structural steel (ASTM A588) with pins from alloy steel (AISI 4340) and fabricated in accordance with the Code of Standard Practice for Steel Buildings and Bridges, Sept 1, 1976, American Institute of Steel Construction.

SLING USAGE

Operational History:
A sling is connected to the aft end of the segment handling ring while the segment is on the rail car. The sling remains connected until the segment is rotated to the vertical position and then it is placed back onto its transportation dolly and disconnected from the crane. The slings were used during the Shuttle program for over 1080 SRM segment offloads.

Maintenance History:
Annual:
Complete sling disassembly to include all pin and bore cleaning, visual inspections and critical weld Magnetic Particle NDE per NASA-STD-8719.9 paragraph 10.4.
Semi-Annual:
Preventive maintenance and visual inspections requiring partial disassembly.
Prior to Each Use:
Visual inspections are performed prior to each use.
A detailed condition assessment was recently performed and both slings are in very good condition.
NOTE: The slings were used during the Shuttle program for over 1080 SRM segment offloads and 30 periodic load tests at 125% SWL with no structural failures found during either visual inspections or NDE post load test inspections.

Test History:
Both slings were proof load tested to 376,000 lbs. (200% of Safe Working Load (SWL) and were annually load tested to 235,000 lbs. (125% SWL). No anomalies or failures reported during NDE post-load test inspections. Slings have undergone 30 Periodic Load Tests.

Sling Rated Load versus Actual Load:
Both slings have a rated SWL capacity of 188,000 lbs.
The SRM working load is 174,500 lbs (~93% SWL).

Storage Provisions:
Both slings are stored inside protected from the environment when not in use.

Planned Future Use:
The slings are planned for use in the RPSF during SRM Pathfinder processing training currently scheduled for October 2015. They will also be used for SLS SRM processing in 2017 to off load segments. Use (cycle life) is expected to be one forth that of Shuttle program.

RATIONALE FOR NON-PERFORMANCE

NOTE: If any of this rationale changes after approval, it is the responsibility of the requesting organization to contact the LDEM, re-submit a non-load-test request form and/or request removal of the sling from the non-load test sling list. Additionally any item on the non-load test sling list is subject to periodic review by the LDEM.

Fracture analysis was performed using NASGRO to determine remaining cycle life based on an NDE minimum detectable crack size.
Structural analysis (KSCL-3231-0904) was reviewed to determine highest stress points which were:

- ASTM A588 Steel: Flange of main beam structural I-beam.
- 4340 Alloy: Pin
- Weld: 3/8 inch weld in highest stressed area.

The minimum crack size and maximum design stress were entered into NASGRO and analysis run for 500,000 cycles.
Results: (see KSCL-3231-0904 Revision A for NASGRO analysis)

RATIONALE FOR NON-PERFORMANCE

ASTM A588 Flange of I-beam: Critical crack size not reached.
AISI 4340 Pin: Critical crack size not reached.
Weld: Not failed at 500k cycles and no imminent failure warnings issued.
Conclusion:
SLS Program SRB sling cycle life assumed to be no greater than Shuttle Program cycle life (~ 1,100 cycles) over 30 years. Fracture analysis indicates a very high probability that a flaw will be detected during visual inspections or NDE prior to a failure occurring.

Recommended Maintenance:
The slings will continue to be inspected in accordance with NASA-STD-8719.9, Paragraph 10.4:
Annual:
Complete sling disassembly to include all pin and bore cleaning and lubrication. Structural member visual inspections and NDE of pins, bores and critical welds.
Prior to Each Use:
Visual inspections will be performed prior to each use.

Both slings are in very good condition and shall be stored inside away from corrosive environment.

Describe the risks, if any, of not performing the load test and how they will be mitigated:

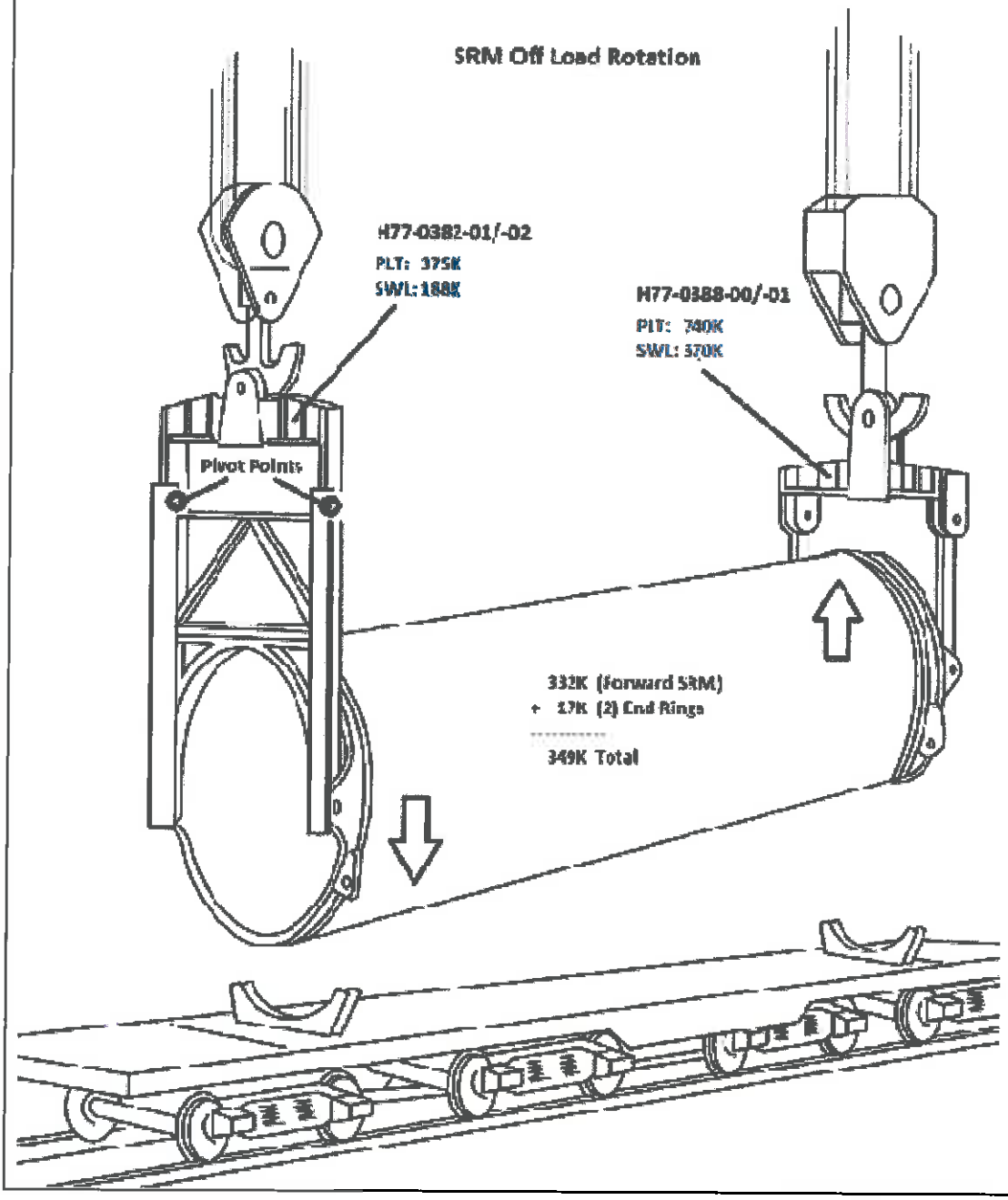
Risk: Undetected flaw could propagate to a critical crack size resulting in structural failure under load.

The risk mitigations for not performing the Annual Load Test are as follows:

1. Fracture analysis indicates > 500,000 cycles remain before a flaw could propagate to critical crack size, expected cycle life over next 30 years < 1,100 cycles.
2. Structural Slings are inspected per NASA-STD-8719.9 paragraph 10.4 including full disassembly and NDE of pins and welds.
3. The NASA Lifting Standard allows for slings that are of "unique design and usage" to be designated as non-load test slings. These slings were designed and are used exclusively for SRB offload and rotation, and their load cases are well understood and repeated.
4. These slings have offloaded over 1080 SRB segments and have undergone over 30 load tests with no structural failures ever found from visual and/or NDE inspections.
5. These slings are periodically loaded to 93% of the SWL during operations. An additional load test does not reduce the risk (5 x 1) as ample mitigations exist.
6. Prior to use preventive maintenance shall include complete sling disassembly and inspection with critical weld NDE in accordance with NASA-STD-8719.9, paragraph 10.4 and the referenced drawings.
7. There will be prior-to-use visual inspections.
8. Slings are stored indoors.
9. Structural analysis (KSCL-3231-0904) verifies a minimum factor of safety of 5 against ultimate and 3 against yield.
10. Initial proof load test conducted at 200% SWL.
11. Personnel performing SRB offload and rotation are trained and follow specific written procedures.
12. Condition assessments were recently performed on both slings and they are in very good condition.
13. The slings will be used first with an inert segment of equivalent mass to a flight segment during SRM Pathfinder processing training before being used with flight hardware.

ADDITIONAL INFORMATION

The Non-Load-Test Sling request for the H77-0382-01 / -02 Structural Slings was presented to The Chief Engineer Review on March 3rd, 2015, and the Program Review Board (PRB) on March 6th, 2015. Both forums concurred with the addition of the H77-0382-01 / -02 Slings to the KSC List of Non-Load Test Slings. See attached presentation from the PRB.



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Jacobs Space Operations Group (JSOG)

Reliability Centered Maintenance
H77-0382-01/02 RPSF Structural Slings

PRB - Decisional

March 6, 2015

Agenda

- Introduction / Purpose
- Description and Use of the SRB Break-over Structural Sling
- Current vs. Recommended Maintenance Approach
- Analytical / Historical Rationale
- Risk Assessment (GORA)
- Summary / Recommendations

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Introduction / Purpose

Introduction:

- Part of the TOSC Ground Systems Maintenance Plan objectives is to execute Reliability Centered Maintenance (RCM) risk-based decisions that identify specific areas to improve the overall effectiveness of system maintenance.
- The H77-0382 (-01 and -02) SRM Break-over Structural Slings are a strong candidate for improved maintenance effectiveness through an RCM approach.

Purpose:

- Provide sufficient analytical, historical and risk-based evidence to support a change from the current maintenance philosophy of the SRM Break-over Sling to a recommended maintenance approach more commensurate with the current operating context.

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Description / Use of SRB Break-over Sling

Description / Use:

- The H77-0382 (-01 and -02) SRM Break-over Structural Slings are used during (SRM) booster segment off-loading at the Rotation Processing and Surge Facility (RPSF)
- Slings are stored indoors protected from the environment when not in use
- SWL = 188,000 lbs
- Sling Proof Load Tested to 376,000 lbs (200% of SWL)
- These slings are needed in late 2015 for *inert* segment offload
- Currently have annual load test requirements and semi-annual inspections requiring partial disassembly.

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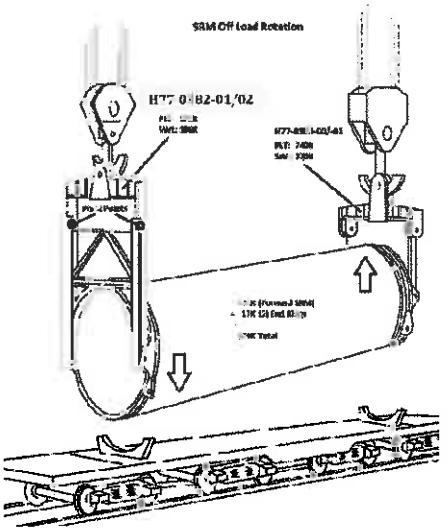
Description / Use of SRB Break-over Sling

- The sling is connected to the aft end of the segment while the segment is on the rail car.
- The segment is rotated to the vertical position.
- The sling is set down onto its transportation dolly and disconnected from the crane



5

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Historical Maintenance and Inspections

- **Annual:**
  - Complete beam disassembly to include all pin & bore cleaning, visual inspections and critical weld Magnetic Particle NDE per NASA-STD-8719.9. Paragraph 10.4.
  - Load test to 235,000 lbs (125% SWL)…(current NASA-STD-8719.9 requirement is 100% SWL = 188,000 lbs)
- **Semi-Annual:**
  - Preventive maintenance and visual inspections requiring partial disassembly.
- **Prior to Each Use:**
  - Visual Inspection prior to each use.

6

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RCM-Based Recommendation

- **Annual** (prior to 1st use, valid for 12 months):
  - Complete beam disassembly to include all pin & bore cleaning, visual inspections and critical weld Magnetic Particle NDE per NASA-STD-8719.9. Paragraph 10.4.
  - Condition Assessment to include visual inspections and preventative maintenance.
  - Designate H77-0382 sling as a Non-Load Test Sling (NLTS) and no longer perform annual Load Test.
- **Semi-Annual**: Remove (preventive maintenance rolled into annual)
- **Prior to Each Use:**
  - Visual Inspection prior to each use.

➢ **Resulting maintenance cost avoidance:**

- $52,000 Labor; $28,000 non-labor (one-time FY15)
- $10,000 labor / year (recurring)

Note: Condition assessments recently performed; both slings in very good condition

7

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RCM Rationale – Robustness of Design

- **H77-0382-01/-02 slings meet the following Design Standard requirements:**
  - KSC-DE-512-SM (Facility systems, Ground Support Systems and Ground Support Equipment general design requirements).
  - KSC-STD-Z-0004F (Structural Design, Standard for)
  - KSC-STD-Z-0002 (Lifting Devices and Equipment, Standard for) – superseded by NASA-STD-8719.9
  - Constructed from Structural Steel (ASTM A588) with pins from Alloy Steel (AISI 4340) and fabricated in accordance with the Code of Standard Practice for Steel Buildings and Bridges, Sept 1, 1976 AMERICAN INSTITUTE OF STEEL CONSRUCTION.
  - Structural Analysis (KSCL-3231-0904) verifies a minimum factor of safety of 5 against ultimate and 3 against yield.
  - Proof Load Tested to 200% SWL.

8

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RCM Rationale – Design Criteria

- **KSC-DE-512-SM and KSC-STD-Z-0004F do not address operational periodic load test requirements.**
  - Only specify design requirements (5:1u / 3:1y) and verification requirements (initial proof load to 200%)
  - Periodic load test requirements fall under NASA-STD-8719.9
- **The NASA Lifting Standard (NASA-STD-8719.9) has provisions to allow Non-Load Tests for specific lifting devices:**

10.3.3 Non-Load Test Slings. Due to [illegible], a sling may be designated as a non-load test sling by the LDEM, with concurrence from the affected/responsible program/project office, the responsible safety, design engineering, systems engineering, operations, and maintenance organizations. Such slings do not require periodic load tests. [illegible] This non-load test designation shall be formally documented by each installation and the sling marked accordingly to designate it as a non-load test sling.

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RCM Rationale – Historical Use

Historical Use:

- The H77-0382 (-01 and -02) slings were specifically designed and are exclusively used for SRB offload and rotation.
  - Load cases are well understood and repeated
  - Not used for any other lifting operation
  - Sling SRM working load is 174,500 lbs (~93% SWL), which is very near the 100% load test requirement.
- Has undergone over 200 visual inspections with no structural failures or discrepancies found.
- Over 1080 SRM segment offloads and 30 periodic Load Tests at 100% SWL have been performed with no structural failures found during either visual inspections or NDE post Load Test inspections.
- Storage is indoors away from corrosive environment.

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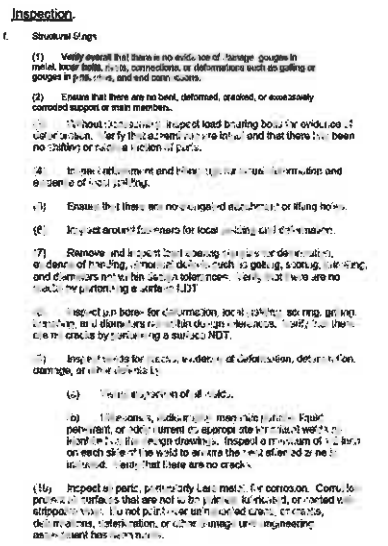
RCM Rationale – Inspections

Recommended Annual Inspections and Maintenance:

- Non-load test slings will continue to be inspected annually in accordance with NASA-STD-8719.9, Paragraph 10.4:
  - Complete beam disassembly to include all pin & bore cleaning, lubrication, etc.
  - Visual inspections of critical welds, pins, bores and structural members
  - NDE of pins, bores and welds including heat affected zones
- Semi-annual inspections (preventive maintenance) is intrusive and poses its own risks (damage, injury…)
- Semi-annual inspection is not justifiable at planned SLS usage rate (1/4 that of SSP)



10.4 Inspection.

f. Structural Slings

(1) Verify overall that there is no evidence of damage, gouges in metal, loose bolts, rivets, connections, or deformations such as galling or gouges in pins, bores, and end connections.

(2) Ensure that there are no bent, deformed, cracked, or excessively corroded support or main members.

(3) Without disassembly, inspect load bearing bolts for evidence of deterioration. Verify that adjustments are installed and that there has been no shifting or relocation of parts.

(4) Inspect attachment and fitting surfaces for deformation and evidence of local yielding.

(5) Ensure that lines are not damaged at attachment or lifting holes.

(6) Inspect around fasteners for local cracking and deformation.

(7) Remove and inspect load bearing pins for deterioration, evidence of fretting, chemical deterioration such as galling, scoring, pitting, and dimensions not within design tolerances. Verify that there are no cracks by performing a surface NDT.

(8) Inspect pin bore for deformation, local cracking, scoring, galling, corrosion, and dimensions not within design tolerances. Verify that there are no cracks by performing a surface NDT.

(9) Inspect welds for cracks, evidence of deformation, deterioration, damage, or other defects by:

(a) Visual inspection of all welds.

(b) Dimensions, additional nondestructive examination (liquid penetrant, or magnetic particle) as appropriate for material, weld configuration, and design requirements. Inspect a minimum of 10 inches on each side of the weld to ensure the heat affected zone is inspected. Verify that there are no cracks.

(10) Inspect all parts, particularly Lead metals, for corrosion. Corrosion protect all surfaces that are not subject to frictional forces, or mated with dissimilar metals. Do not paint over an unresolved crack, corrosion, deterioration, or other damage until engineering assessment has been made.

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RCM Rationale – Fracture Analysis

Fracture analysis was performed using NASGRO to determine the cycle life to failure based on an NDE detectable crack size.

- Minimum detectable crack size was determined from NASA-STD-5009 (Non-Destructive Evaluation Requirements for Fracture-Critical Metallic Components)
  - For Magnetic Particle NDE two limit cases listed (a x c dimensions):
  - .038" depth x .188" length and .075" depth x .125" length
- Structural Analysis (KSCL-3231-0904) was reviewed to determine highest stress points:
  - A588 Steel: Tension in flange of main structural I-beam mid-way of span due to bending stresses (Margin of Safety = 0.03)
  - 4340 Alloy: Bending stress in Pin (Margin of Safety = 0.20)
  - Weld: 3/8" weld in highest stressed area
- Minimum crack size and maximum design stress was entered into NASGRO and analysis run for 500,000 cycles.

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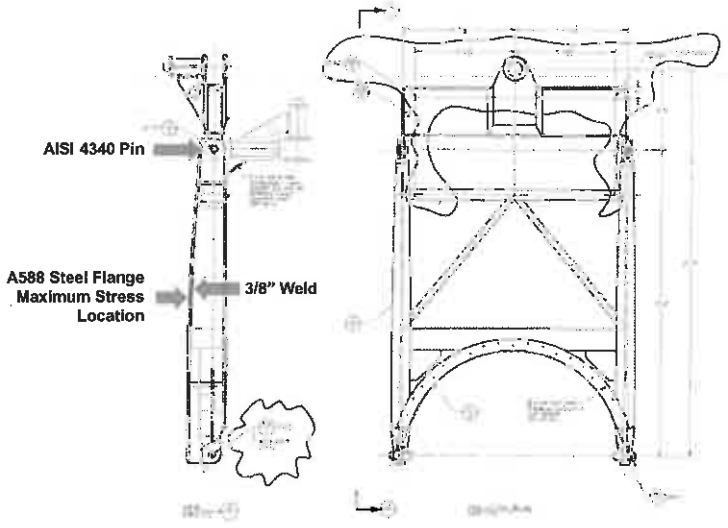
RCM Rationale – Fracture Analysis



13

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RCM Rationale – Fracture Analysis

Fracture Analysis Results:

- ASTM A588 Flange of I-beam:
  - Critical crack size not reached at 500K cycles
  - Crack size at 500K cycles: 0.25" long
  - Run to failure critical crack size > 4 inches
- AISI 4340 Pin:
  - Critical crack size not reached at 500K cycles
  - Crack size at 500K cycles: 1.3" long
- Weld:
  - Not failed at 500K cycles and no imminent failure warnings issued
  - Crack size at 500K cycles: 0.25" long
  - Run to failure critical crack size > 5 inches

Conclusion:

- SLS Program SRB Sling cycle life assumed to be no greater than Shuttle Program cycle life (~1,100 cycles) over 30 year period.
- Fracture analysis indicates a very high probability that a flaw will be detected during visual inspections or NDE examinations prior to a failure occurring during use or Load Test.

14

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GORA Risk Assessment

Risk Assessment Matrix

	Risks	Consequences		Likelihood	Risk Score	Mitigations or Recommendations
		Category	Score			
1.	Failure to detect a structural anomaly in the H77-0382 Handling Beam could result in dropping of a SRM segment and loss of life/flight hardware.	Safety – Loss of life/flight hardware.	5	1 Highly Unlikely (Extremely remote possibility of occurrence, strong controls in place).	5	Designed per the requirements of KSC-DE-512-SM, KSC-STD-Z-0004F and NASA-STD-8719.9. Designed with a minimum factor of safety of 5 against ultimate and 3 against yield. The beam has been Proof Load tested to 200% of its rated load. Annual preventive maintenance and visual inspections are performed. Annual complete beam disassembly to include all pin & bore cleaning, visual inspections and critical weld Magnetic Particle NDE. Visual inspection performed prior to each use.

Risk Assessment Based on No Annual Load Test

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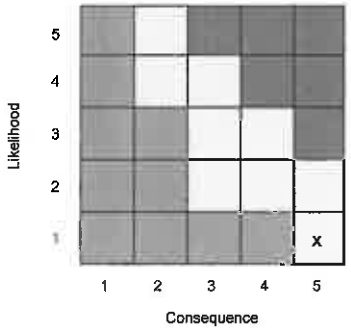
15

Risk Assessment (Cont.)

TOSC Risk Management Scorecard Matrix



**** Inclusion of Annual Load Test does not decrease Risk ****
Mitigations provided by the proposed RCM plan are sufficient to reduce risk to its lowest level

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16

Summary / Recommendation

1) Recommend removing Semi-Annual inspections and preventive maintenance and performing at an Annual interval
   - 30 yr inspection history (including 60 partial disassemblies) indicates annual inspections are adequate
   - Slings are stored indoors
2) Recommend adding the H77-0382 (-01 and -02) SRM Break-over Structural Slings to the Non-Load Test Sling (NLTS) list.
   - The H77-0382 (-01 and -02) slings were designed and are used exclusively for SRB offload and rotation.
   - Slings have offloaded over 1080 SRB segments and have undergone over 30 load tests with no structural failures ever found from visual and/or NDE inspections.
   - Load Test does not reduce Risk (5 x 1). Ample mitigations exist without the use of periodic load test.
   - Fracture analysis indicates inspection will detect issue prior to a failure occurring during use or load test.

17

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